Cognitive Development

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Accommodate To change one's concept on the basis of new knowledge.
Assimilate To take in a new information and incorporate it into an existing concept.
Concept An abstract or generic mental representation generalized from particular instances.
Habituation Decrease in responsiveness upon repeated exposure to a stimulus.
Stage Theory Assumption Development occurs through qualitatively different stages in a given order.

The study of COGNITIVE DEVELOPMENT is concerned with how our young come to share with us knowledge about the world of objects, people, and ideas. Answering these questions requires suitable methods of observation and experimentation, on the one hand, and good ideas about what to look for, on the other hand. Often what one looks for is tied to one's theories about cognitive development, in general, and the nature of concepts, in particular. This essay begins by asking "what is a concept" and embeds in the answer a review of theories of cognitive development and relevant findings. Evidence for the conclusion that there are some universal (core) kinds of concepts is presented.

I. ABOUT CONCEPTS

Our concepts do not stand alone, each separate from the other. For example, our concept of a dog is related to our knowledge of other animals, and our concept of a bicycle is related to what we know about other wheeled artifacts. Concepts are organized into coherent groupings or structures; at the same time, what we know about one concept in a grouping is interrelated with what we know about others in the same organization. This fact about mental organizations is extremely important. It underlies our ability to generalize what we know to novel instances in the same conceptual structure, to make inferences about the meaning of names for new objects, and so on. When we are told that a picture of an unfamiliar animal depicts a species living in a far-away place, we can infer that it is the kind of thing that breathes, eats, reproduces, probably makes communicative noises, has sensory receptors, interacts at least some times with others of its kind, and is capable of moving itself from place to place. Such inferences are possible even if we will never see the animal and despite the fact that, in a picture, it resembles a cactus. When told the creature is an echidna, we will assume that all items that look like it are also echnidas and will be able to answer questions that refer to it, for example, "Does an echidna bear young?" versus "Does one wear an echidna in cold weather?" Our understanding of the world is not a collection of random facts joined together by pairs of associations. Therefore, when we are told that an unknown animal is an echidna, we do not have to start from scratch and build an understanding of the animal as described above, one piece at a time.

The challenge for students of cognitive development is to characterize how our young accomplish the task of acquiring concepts and the related abilities to apply them to novel cases. Any answer to this question must account for the fact that children do not merely develop concepts. We need to explain how they develop concepts that they share with others and therefore can communicate about. Psychologists' realization that knowledge about concepts is organized goes hand in hand with a new theoretical concern in cognitive development—the nature of domain-specific knowledge structures and how they develop.

II. AN OVERVIEW OF COGNITIVE DEVELOPMENT THEORIES

There are at least five different kinds of accounts ofcognitive development. Learning theory account is based on the assumptions of associationism: All knowledge is due to sensory and motoric experiences and the capacity to form associations. Information processing theorists focus on the role of information processing and problem solving capacities for explaining how children learn to understand the world. With time, experience, and practice, children acquire organized memories and develop ways to circumvent processing limits on attention, short-term memory, and perception. Learning theory and information processing accounts of cognitive development share the assumption that cognitive development is a linear function of experience. The sociocultural account of cognitive development places emphasis on the assumption that concept acquisition is facilitated by infants' inclinations to pay attention to the social agents who serve as transmitters and presenters of key information. Still, it shares the assumption that the acquisition of concepts is a protracted process, taking as much as two years before a child reaches the point where he or she has the ability to represent the world in terms of concepts and to communicate with others.

Some sociocultural theorists like Vygotsky incorporate a stage theory assumption, showing development as a passage through qualitatively different stages in a given order. At each stage, the child actively engages the environment with existing structures of mind so much that it is possible for the child to "misinterpret" inputs about concepts. For example, in Piagetian theory, cognitive development proceeds through four stages: from the sensorimotor (0 to 2 years of age), to preoperational (2 to 5 or 6 years), to concrete operational (6 to 10 or 11 years), and finally, the formal operational (12+ years) stage. The Piagetian child who is still at the preoperational stage will fail to conserve quantity across transformations because she still has to acquire the structures that will support quantitative reasoning, a hallmark of Piaget's concrete operational stage. At the preoperational stage, children also fail perspective-taking tasks as a result of focusing on their own views.

The fact that all four theories named above differ in notable ways becomes more apparent in studies of post-infancy cognitive development. For example, since scholars working in the information processing tradition emphasize the general limits on processing, they do studies that show how success varies as a function of real-time processing demands. Those who emphasize the social aspects of cognitive development might focus on the acquisition of shared conversational rules. Despite the fundamental differences, all four classes of theories converge on a common view about infant cognition. This view is that infants come to the world without any mental structures that relate to the kind of conceptual, linguistic, and social world they will live in. The general idea for association, information processing, and stage theories is that infants first learn about sensory and action experiences. These lay the foundation for developing perceptions which in turn form the basis upon which concept acquisition can proceed. The cultural account also shares the sensation to perception to cognitions view of development; but it adds the assumption that acquisition is facilitated by infants' inclinations to pay attention to the social agents who serve as transmitters and presenters of key information.

Thus, all four of the above theoretical accounts embody the view that the start of concept acquisition takes as much as 2 years to get off the ground, to reach the point where the child has the ability to represent the world in terms of concepts. On first blush, this seems reasonable. After all, newborn infants are extremely helpless and human infants take a fairly long time to get beyond the many limits on their motoric, sensory, and communicative abilities. The delayed onset of language use until around 2 years of age is consistent with the ideas that neonates' conceptual knowledge is nonexistent and that of older infants is extremely shallow. Indeed, one might ask, how could anyone think otherwise? Those who answer to the contrary do so because of the accumulating body of evidence that infants, toddlers, and preschoolers have some remarkable conceptual competencies. Such evidence, some of which is presented below, has contributed to the emergence of a fifth theoretical account of cognitive development that can be dubbed a rational-constructivist theory of cognitive development. The rationalist side of the theory captures the assumption that our young bring a skeletal outline of domain-specific knowledge to their task of learning the initial concepts they will share with others. The constructivist side of the theory captures the assumption that, from the start, our young actively join in their own cognitive development. Even as beginning learners, skeletal principles motivate them to seek out and assimilate inputs that nurture the development of these structures.

Like stage theorists, rational-constructivist proponents hold that there are universal structures of mind. These theories differ, however, on whether there is some innate conceptual knowledge at the start. Piaget held that the processes of assimilation and accommodation are innate, but he denied the presence of any innate structures of mind. In contrast, the rational-constructivist position joins two assumptions: innate inclinations to actively process (assimilate and accommodate) the environment, along with an assumption of innate skeletal structures of knowledge. The rational constructivist position also differs from stage theories in its commitment to the view that there are domain-specific, as opposed to domain-general, structures of mind. For example, whereas Piaget's theory grants the mind general structures such as concrete operations, rational constructivist theories hold that different knowledge domains, for example, number and space are represented by domain-specific structures. Universally shared domains, also called core domains, benefit from innate, skeletal, domain-specific structures. The common underlying set of skeletal, domain-specific structures are learning-enabling engines of mind. Given that infants actively apply whatever structures of mind they might have—skeletal or otherwise—data (i.e., inputs from the environment) that have the capacity to nurture these structures are privileged as targets of attention and then assimilation to the structures. As a result, these data nurture rapid learning about many of the objects and events they encounter. As skeletal as these structures might be, they nevertheless facilitate selective attention and assimilation of structure-relevant data and therefore serve much like engines of learning about their domains.

We turn to evidence, starting with the fact that infants learn quickly about core domains of knowledge. Thereafter, the text turns to a review and assessment of some of the classical experiments, the traditional interpretations of these, and then examines ways to reconcile the seeming differences between the new and old findings. To end, we discuss the fact that, although people all over the world develop core concept domains, with or without formal instruction or intentional practice, acquisition of noncore domains is much more idiosyncratic. The development of conceptual mastery in noncore domains requires organized lessons, study, and years of learning.

III. EVIDENCE

A. Recent Findings about the Capacities of Infants

In their 1973 pioneering study, Kalnins and Bruner showed that infants use their well-developed sucking responses to explore and learn about the world of objects and even representations of them. Not only will infants suck on a nipple (specially constructed with a transducer linked to a recording machine) to get access to an interesting picture, they learn to adjust the rate at which they suck in order to bring the picture into focus. Young infants also adjust their sucking rate, signaling when they are bored with a particular picture. They habituate; that is, they slow their sucking in the presence of a given picture and thereby let it go out of focus. Given a new picture, infants once again resume sucking at a high rate. This conjugate reinforcement method is also used to show that 1-month-old infants are capable of making categorical distinctions between different phonemes, for example, ba and pa, la and ra.

The discovery that infants have potent tendencies to attend actively and learn about novel inputs quickly turned into a major research tool for investigations of infants' perceptual and conceptual abilities. Across a range of studies, infants have attended to and learned about a wide range of structurally complex data. Six-to 8-month-olds can match the number of items they see with the number of drumbeats they hear. Young infants also know that objects continue to exist even when they cannot see them. Other studies expand on these conclusions, as described below.

Baillargeon and her colleagues provide evidence that infants interpret motion paths for inanimate objects in ways that are consistent with an external-agent causal principle. That is, inanimate objects require a source other than themselves to move. Baillargeon, Spelke and Wasserman's demonstration of object permanence in 6- to 8-month-old infants is one example of this. In their 1985 experiment, infants saw the same motion path at two different times. First, during the habituation phase, infants saw a screen rotate towards and away from them, through a 180° arc. Nothing was behind the screen. When their interest in the moving screen declined, that is when the infants habituated, the experimenters set the stage for creating the viewing conditions of the same 180° rotating screen for a second time. This time, the experimenter showed infants an object placed to the left side of the rotating screen. While infants watched, the experimenter moved the object behind the screen while it was upright. Then the post-habituation phase of the experiment began. Once again, the screen rotated toward and away from the infant. On alternating trials it either traversed a novel 120° arc or the familiar 180° arc. Given that there was an object in the path of the rotating screen, the screen should have stopped at about the 120° position of its rotation. When it continued through a 180° arc (thanks to the use of trick mirrors and invisible doors), it contributed to the adult perception of an impossible event, an unseen block being repeatedly crushed and uncrushed as the screen circumscribed its 180° arc. The event is impossible for adults because for them—save in the world of spirits and ghosts—one solid object cannot move through another one. If infants are restricted to perceptual analyses of motion paths, they should see no difference between 180° arc rotation that was shown in both the habituation and post-habituation phases. They should therefore continue to be uninterested in this event and prefer to look at the 120° event, the one that generates a novel perception. If, however, infants interpret the motion paths in terms of causally relevant variables, they should treat the second showing of the 180° event as different from the first showing of the 180° event. In fact, they attended more to the 180° event, from which we conclude that infants interpreted the perceptual information about the motion path in ways that we know are causally relevant.

Studies by Spelke and colleagues demonstrate that 7-month-olds know that, whereas two inanimate objects have to contact each other if a causal event that involves them is to occur, the same is not true for two people. To show this, the authors constructed infants' reactions to two pairs of videotaped displays. The inanimate pairs of stimuli were two 5- and 6-ft. tall objects that had distinctive novel shapes and contrasting bright colors and patterns. The animate pairs were two people. In the inanimate test condition, infants watched two events: (a) the objects moved toward each other, touched each other, and changed direction; (b) the objects moved toward each other, stopped before reaching the point of contact for a brief time, and changed direction. In the people condition, the structure of the two events was identical to that of the inanimate events. For example, the parallel event for the person-contact condition showed a person holding her arms up and close to her body as she brushed up alongside another person. During test conditions, infants looked reliably longer at the no-contact inanimate event; they showed no such preference in the animate event trials. Spelke's findings are buttressed by other findings that 9-month-old children organize their exploration of toys so as to keep examples of animals and vehicles in separate categories.

These demonstrations are especially surprising given the longstanding assumption that infants enter the world with a mind that is a blank slate and only the abilities to sense bits of light, sound, and so on. Piaget's idea that these perceptions are brought together as bits of schemata and the associationist view that infants gradually contribute to the building of associations about these punctate sensory experiences are consistent with the widespread belief that infants start out in a "blooming, buzzing, confusing" world. It is therefore no surprise that researchers have challenged the idea that studies like those presented above demonstrate early conceptual competence and instead try to find "simpler" explanations. Nevertheless, the continued demonstrations of early competence provide a series of converging lines of evidence. This makes it harder and harder to reject the viability of some variant of the rational-constructivist theory. The challenge remains to reconcile the traditional findings with the new findings, not to try and explain away the new. That is, it is important to take a hard look at the studies showing infants do have concepts and can learn rapidly about numbers, causes, categorical differences between animate and inanimate objects, and people, and then ask what distinguishes these studies from those that do not.

B. Some Traditional Findings

Some of the best evidence in favor of stage theories comes from the various classification tasks that Bruner, Piaget, and Vygotsky used. Across a set of different tasks, preschool-aged children will fail to apply a classification structure. That is, they do not use consistent criteria to sort a pile of objects, be these different colors and shapes; and they do not solve problems that require reasoning about the hierarchical relationships between superordinate and subordinate categories. For example, when children who were 7-years-old or younger were asked whether a bouquet of flowers made up of six roses and four tulips contains more roses or flowers, children invariably answered, "More roses."

Other results add weight to the idea that young children cannot classify consistently. Specifically, children will not pick out all and only those exemplars that are examples of the concept. In a study in Bruner's lab, subjects ranging in age from 6 to 19, heard a series of concrete nouns and had to answer how each new item was both similar to and different from a pair of items presented. For example, a child first heard "banana," "peach," and then "potato." Then she was asked, "How is potato different from a banana and peach and how is it similar?" The youngest children answered on the basis of perceptual attributes like color and size, not categorical membership or even functional similarity. In a second task, participants were shown a large number of photographs and then asked to pick out groups that were alike. Again, responses of the young children were based predominantly on shared perceptual attributes as opposed to shared conceptual criteria.

Vygotsky described a similar pattern of findings, with younger children focusing on common perceptual or thematic criteria. Given the robustness of the developmental classification data, it is easy to see why so many people believed that preschool-aged children have pseudoconcepts, pre-concepts, or idiosyncratic concepts that lead them to put together items older children and adults would never put together. From such results, it is an easy step to infer a stage theory that says older children and adults have mental structures that support hierarchically organized concepts, but young children, toddlers, and infants do not. This is especially so when we consider the many cases where younger children seem indeed to be perception-bound, as Piaget's conservation tasks suggested.

Preschool children's persistent failure on Piagetian conservation tasks is used as a salient example of their reliance on surface perceptual attributes of the displays. When shown two identical glasses with equal amounts of water that obviously reach the same level, all children aged 4 to 8 years of age agree that two amounts are equal. However, when one glass is poured into a tall, thin beaker, the 4- and 5-year-olds deny that equivalence is maintained, either because one column of water is taller or one is shorter. Piaget's work on early causal reasoning adds weight to the idea that preschoolers reason on the basis of the superficial appearance of things. For example, young children seem to think that the sun and the moon move when (and because) they themselves are moving.

Turning to infants, there are the traditional Piagetian tests of object concept and the famous "A-not-B error" that is characteristic of 8- to 12-month-old infants. At this range, infants will reach out for an object (say, a toy), watch as it is covered, and even remove the cover to get the hidden object. However, if, while the baby is watching, the object is put under a second cover, the infant no longer uncovers the desired toy. Instead she continues to look under the first cover where they toy no longer is. An amazing performance! It is as if the infant believes the existence of the object is related to his or her own earlier successful action and not that an object is a permanent entity that continues to be somewhere "out there." That is what Piaget concluded and what many take to be true.

C. Contradictory Findings?

The main question one has to ask about seemingly contradictory findings is this: Is there a coherent interpretation of performance variability within and across conditions? Is it possible that there are systematic variables contributing to failure across tasks that are meant to tap the target competence in question? If so, it may be possible to validate interpretations of competence with either new evidence or manipulations of the hypothesized interfering variable.

Infants are immature planners and information processors. Piaget's tests of the infant's understanding of the object concept all require the deployment of a competent plan of action. However, if the planning system needed to generate a competent plan of action is limited or not even developed, then the risk is high that a child will fail no matter how much she knows about the content domain at hand. There are reasons to presume that infants' abilities to generate coordinated actions go through a protracted developmental course. Therefore, perhaps Piaget's conclusions about the development of object permanence are better thought of as gains in infants' abilities to assemble suitable plans and related action sequences.

To start, we know that the information processing demands of a task vary as a function of development. In a 1991 study Diamond reported clear effects from varying the time before an experimenter allows the infant to reach for the hidden object. If the delay between the end of the hiding phase and the beginning of the retrieval phase is less than 2 seconds, 7½- to 8-month-old infants do not make the A-not-B errors instead they look for the object in its second hiding place. If the interval exceeds 2 seconds, they make the standard error of seeking the object in the original hiding position. By 9 months of age, infants can succeed after delays of up to 5 seconds, and by 12 months can do well on delays of up to 10 seconds. Other studies show that infants who erred had a clear tendency to choose an item that was near the first hiding place, thereby adding another dimension to what we know about information processing demands in the A-not-B task.

Limits on memory are not the only factor hindering the immature infant's ability to reach for the item in the correct location. Diamond details a number of variables that limit 5- to 7-month-old infants' ability to assemble and produce a competent plan of action. For example, younger infants have trouble inhibiting reflexes that are elicited if they accidentally touch an object that happens to be near the one they have to get. Baillargeon, Kotovsky, and Needham make it clear that the requirements of the task (i.e., ones that are not tied to knowledge about object permanence), can mask the infant's knowledge of objects. In a 1995 study, they showed that 5-month-old infants know the difference between actions that can and cannot support the retrieval of an object that is hidden behind a screen. In one experiment, infants watched an object being retrieved under a possible and impossible action condition. To set the stage for the relevant part of the experiment, infants first watched one of two hiding events. One involved showing the hand of an experimenter placing a teddy bear on a table; a screen was then moved in front the display, and infants saw a hand reaching behind the screen and pulling out the teddy bear—a perfectly possible event. In the other hiding event, a teddy bear was placed on a table with a transparent cup over it and then a screen was moved to occlude the display. Then, while the screen was in place, the infant again watched as the experimenter's hand reached behind the screen and pulled out the teddy bear—an impossible outcome. Infants responded differently to these two different events by showing surprise and looking longer at the impossible event condition. Thus at least some of the differences in results from studies using reaching tasks rather than looking habituation paradigms to evaluate object permanence in infants has to be attributed to general limits on their ability to produce suitable action sequences. There is much to learn about the development of action planning, and therefore procedural competence, during the first few years of life.

Infants in habituation and visual preference studies have been tested under a wide range of stimulus conditions, including ones where balls fall to the floor, trains go down tracks, blocks and toys are hidden, and objects are felt but not seen. The studies that show infants are able to discriminate between relevant and irrelevant retrieval acts and succeed on Piagetian tasks, if they are tested under the right conditions, help corroborate the conclusions that were based on habituation methods. Additionally, they give further reason to argue that part of what develops is an ability to relate conceptual competence to procedural competence.

Thus, there is a sense in which Piaget was right to focus on the role of action in thought. However, for Piaget thought and action are almost one and the same. An alternative view assumes that infants start life with immature and limited abilities to perform, let alone put acts together into a competent plan that can demonstrate underlying conceptual competence.

It is wise therefore, to use assessment techniques that minimize demands on the procedural side if the question of interest concerns conceptual competencies that infants might have. A better approach is to find and use more than one such method, or at least vary the test materials across experiments. As these variations increase, so does one's confidence in the attribution of conceptual competence. Because there are many different studies of very young infants' ability to treat objects as permanent, we are now able to show that there are systematic sources of variability of performance in Piaget's tasks that are not due to the kinds of conceptual limits Piaget would want us to place on infants.

Conversational rules can confound assessments. The experimental setting often violates the rules of everyday conversations, especially the rule that one should not repeat what already is known by the listener. A question about available information presents an especially flagrant violation of that rule. Yet this typically occurs in experiments with young children. Imagine the quandary of a child who knows not to say the obvious when shown five items and is asked by an adult, "How many?" She knows the experimenter knows the answer, so she may do one of the following: violate a rule of conversation and state what she takes to be obvious, find something else to talk about, or decide to remain quiet. Even if a child realizes that she is supposed to tell what anyone could know, there is a further hurdle. In many studies of cognitive development the same question is asked more than once, and the repetition often follows right on the heels of the question's first presentation. There is nothing malicious about this. Researchers often want to know how children respond to irrelevant transformations of the stimulus arrays. Still, from the child's perspective, she must answer once again even though everyone in the conversation knows the answer. It therefore should be of little surprise when the child changes her answer or brings up another subject to talk about.

Because we are not supposed to repeat what is known, the child who shares knowledge of verbal counting principles with an interviewer might assume that it is sufficient to provide the cardinal value or count when answering the question, "How many?" When a speaker counts aloud, there is no need to repeat the last count to signal its status as the cardinal value of the set; the auditor can hear the last count word. It would be a violation of conversation rules to signal something so obvious to an adult listener. Conversely, a statement of cardinal numerosity may be taken to imply that there was a count. These suggestions are more than speculations; they are supported by a study in which undergraduates were asked the "How many?" question about 18 blocks. All of them counted aloud but only one bothered to repeat the last count word. Repeats of the question elicited puzzlement, some recounting, and so on; the responses suggest we violated the conversational rule, "Don't ask about what has been communicated"—in this case the numerosity implied by the count. The implication is clear: Repeating the "How many?" question risks confounding assessments of interpretative and conceptual competence.

Because the experimental setting is hardly an everyday experience for any major culture or ethnic group of preschool children, we might expect the rules that apply here to be relatively late to develop—even for those who are encouraged to initiate talk about what they know. A particularly interesting illustration of this comes from a finding that 4- and 5-year-old children who "fail" the two-question conservation task probably do so because they are motivated to please the experimenter. Researchers had children watch puppets who either passed or failed conservation tests. The children were to indicate whether the puppets' answers served to "tell what they knew" or "please the experimenter." The children said that the nonconserving puppets were trying to please the experimenter and that the conserving puppets were telling what they knew. These findings are relevant to any situation where children must answer the same question again and again, as for example, in a therapeutic interview or court setting.

Toddlers and preschoolers are novices in noncore domains. It is hard to underestimate the effect that knowledge about a domain has on anyone's ability to engage in sensible problem solving, produce coherent classifications, and reach inferences. A given set of principles, the rules of their application, and the entities to which they apply together constitute a domain. Different domains are defined by different sets of principles. Therefore, we can say that a body of knowledge constitutes a domain of knowledge if we can show that a set of interrelated principles organizes its rules of operation and entities. For example, the mental operations of addition and subtraction in combination with the cardinal (count) numbers constitute one domain. The intuitive understanding of principles of mechanics, as applied to objects and their motion and existence conditions, make up another domain. Note that from this perspective, discrimination learning tasks or general processes like problem solving do not constitute a domain.

Some of the many domains that people can acquire have an innate basis but not all domains are core domains. Core, or innate, domains are universally shared; they develop from a common set of existing skeletal structures. Given their presence, learners already have the wherewithal to find and assimilate relevant data. If the data are present in the surrounding environments, learning can proceed without the explicit help of others. In this sense, learning can take place "on the fly," as the learner encounters domain-relevant inputs to assimilate to an existing structure. Learning in a noncore, novel domain, however, must proceed without the benefit of even a skeletal structure, so the acquisition of knowledge in the domain will be more difficult.

Extensive work on the differences between adults who are novices and experts underscores this point. In one study, novices and experts were asked to sort physics textbook problems in any way they wished. Novices did so on the basis of the perceptual aspects of the diagrams or the apparatus; for example, inclined plane and pulley problems were grouped separately. Experts classified the problems on the basis of underlying physics principles needed to solve the problem, for example, Newton's Second Law. They were able to apply the organizing principles of their acquired (noncore) domain of knowledge to the different problems. Because the novices did not share this principled knowledge, they did not categorize the problems based on the laws of physics. Therefore, they could either use a default strategy based on perceptual cues to classify problems, or map the input to whatever existing mental structures they had available. Both kinds of strategies were used: the former are classified as examples of perceptual solutions, the latter as examples of misconceptions. Neither are examples of conceptual understanding on the part of the novices. Yet it is unlikely that a reader would conclude that the adults in this study were at a stage of cognitive development that is best characterized as perception-bound. Instead, one might argue that in order to gain an understanding of Newtonian physics, one needs extensive time to build up new conceptual structures. These new ones differ from those that serve our everyday cognitions about objects in the world, which are more qualitative than quantitative in form. Further, one might ask whether the conceptual structures for children and adults are all that different when the focus is a core, as opposed to a noncore, domain of knowledge. The animate–inanimate distinction is an example.

Young children, as a group, know a great deal about the different kinds of causes for movement. Massey and Gelman showed this in their 1988 study of whether 3- and 4-year-old children are able to indicate whether novel objects depicted in photographs could move themselves both up and down a hill. The pictures showed objects drawn from five categories: mammals, nonmammals, statues that share animal parts, wheeled devices, and rigid complex objects. The young children were extremely good at the task. They did not rely on surface perceptual similarity rule. For example, they denied that statues could move by themselves even if they had arms and legs. When probed further, children left no ambiguity in their replies, saying, for example, "does not have real legs," or "just a furniture-animal." Gelman also found that young children can give sensible answers to questions about the insides of objects, a result that complements their knowledge that animates and inanimates use internal rather than external sources of causal energy.

The literatures on early numerical and spatial concepts add weight for a theory that assumes very young children are inclined to learn about some domains with facility. The case for an early principled understanding of addition and subtraction in combination with counting principles that render cardinal representations of collections is supported by a variety of converging lines of evidence. Preschoolers can detect principled counting errors, invent counting strategies to solve addition and subtraction problems, and deal with novel counting problems. They can also disambiguate ambiguous instructions and settings. Cross-cultural work shows commonalities in how young children learn the first nine digits in count lists and in error patterns in addition and subtraction.

IV. FROM CORE TO NONCORE DOMAINS OF KNOWLEDGE

The young child's competence with natural numbers does not guarantee clear sailing when it comes to learning numerical concepts that are not represented by a core domain. This is a problem for all theories of cognitive development. Movement to formal operations, whether one is a school-aged child or college-educated adult, does not assure parallel passage to understandings of probability, rational numbers, mechanics, evolution, and chemistry. This is a startling fact given the Piagetian school's emphasis on these in the discussions of formal operations. People all over the world have a persistent problem with the concept of rational numbers, even with years of instruction, which constitutes a serious challenge to associationist theories of concept learning. Despite a great deal of exposure to examples meant to foster associative strength for new concepts, there is little advance toward learning these with understanding.

In the end, new understanding in a domain will proceed rapidly when the structure of the target domain is consistent with that of the existing mental structure. However, if the structure of the target domain is different from existing knowledge structures, new learnings will be difficult to acquire. In order for learning with understanding to occur in a noncore domain, the mind has to acquire both the structure and the domain-relevant database of the novel domain. Learning in noncore domains can be handicapped for a straightforward reason: there is no domain-relevant structure, not even a skeletal one, to start the ball rolling. This means that the mental structures have to be acquired de novo for noncore domains like chess, sushi making, computer programming, literary criticism, and so on. In these cases, learners have the twofold task of acquiring both domain-relevant structures and a coherent base of domain-relevant knowledge about the content of that domain. It is far from easy to assemble truly new conceptual structures and it takes a very long time. Some training such as formal instruction is usually required, and still this is not effective unless there is extended practice and effort on the part of the learner. Efforts to provide domain-relevant instruction in noncore domains must recognize and overcome a crucial challenge: Learners may assimilate inputs to existing conceptual structures even when those inputs are intended to force progress in the mental structures and conceptual change. That is, learners may fail to interpret novel inputs as intended and instead treat it as further examples of the understanding they currently have. The risk for this happening is especially high in mathematics classes, to give one example. Harnett and Gelman illustrate this contrast between learning in core and noncore domains. They contrasted elementary school children's rapid acquisition of understanding that every natural number has a successor with their painfully slow progress in understanding rational numbers. The difference is so pronounced that high school and college students around the world cannot be counted on to interpret rational numbers correctly.

V. SUMMARY

The evidence favors a theory that posits skeletal structures and grants the mind an ability to use them and engage actively in its own cognitive development. Domain-specific and stage theories are consistent with this conclusion and present challenges for domain-general theories of conceptual change. A domain-specific theory is consistent with the idea that development involves qualitative shifts in understanding, especially regarding advanced understanding of mathematics, science, and the acquisition of other noncore expertise that characterizes master chefs, chess players, professors of psychology, and so on. Success in these latter domains requires the construction of new conceptual structures, something that is extremely hard to do. Building these structures requires mastery of the specialized language and tools of the domain. As an example, second language learning for adults is never easy. Ponder then, the problem of mastery when there is no understanding of the concepts to which the specialized language maps onto, and we see then that cognitive development is a lifespan endeavor.

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